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Date: October 20, 2000

Docket No.: 630-1165P

BOX PATENT APPLICATION
Assistant Commissioner for Patents
Washington, DC 20231

Sir:

Transmitted herewith for filing is the patent application of

Inventor(s): Min-Cheol HONG and Yoon-Seong SOH

For: FILTERING CONTROL METHOD FOR IMPROVING IMAGE QUALITY OF BI-LINEAR INTERPOLATED IMAGE

Enclosed are:

- ☒ A specification consisting of Eighteen (18) pages
- ☒ Four (4) sheet(s) formal drawings
- ☒ An assignment of the invention
- ☒ Certified copy of Priority Document(s)
- ☒ Executed Declaration (☒ Original ☐ Photocopy)
- ☐ A statement (☐ original ☐ photocopy) to establish small entity status under 37 C.F.R. § 1.9 and 37 C.F.R. § 1.27
- ☒ Preliminary Amendment
- ☐ Information Disclosure Statement, PTO-1449 and reference(s)
- ☐ Other:

The filing fee has been calculated as shown below:

			LARGE ENTITY	SMALL ENTITY
	BASIC FEE		$710.00	$355.00
	NUMBER FILED	NUMBER EXTRA	RATE FEE	RATE FEE
TOTAL CLAIMS	18- 20 =	0	X 18 = $0.00	x 9 = $0.00
INDEPENDENT CLAIMS	2- 3 =	0	x 80 = $0.00	x 40 = $0.00
☐ MULTIPLE DEPENDENT CLAIMS PRESENTED			+ $270.00	+ $135.00
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☒ A check in the amount of $750.00 to cover the filing fee and recording fee (if applicable) is enclosed.

☐ Please charge Deposit Account No. 02-2448 in the amount of $0.00. A triplicate copy of this transmittal form is enclosed.

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If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17; particularly, extension of time fees.

Respectfully submitted,

BIRCH, STEWART, KOLASCH & BIRCH, LLP

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GDY/cpw
630-1165P
Attachments

(REV. 09/29/2000)

PATENT
630-1165P

IN THE U.S. PATENT AND TRADEMARK OFFICE

Applicant:	Min-Cheol Hong et al.		
Appl. No.:	New	Group:	Unassigned
Filed:	October 20, 2000	Examiner:	UNASSIGNED
For:	FILTERING CONTROL METHOD FOR IMPROVING IMAGE QUALITY OF BI-LINEAR INTERPOLATED IMAGE		

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, DC 20231

October 20, 2000

Sir:

The following preliminary amendments and remarks are respectfully submitted in connection with the above-identified application.

IN THE CLAIMS:

Please amend the claims as follows:

Claim 8

Line 2, delete "or 6".

Claim 15

Line 2, delete "or claim 13".

Please add the following new claims:

--17. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 6, the number of a kernal of the PSF(P) is set in accordance with an up-sampling value of the image.—

--18. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 13, the number of a kernal of the PSF(P) is differently set in accordance with an up-sampling value of the image.--

REMARKS

Claims 1-18 are pending in the present application. Claims 8 and 15 have been amended to remove multiple dependencies. Claims 17 and 18 have been added to recapture subject matter that was deleted from claims 8 and 15.

Entry of the above amendments is earnestly solicited. An early and favorable first action on the merits is earnestly solicited.

Should there be any outstanding matters that need to be resolved in the present application, the Examiner is respectfully requested to contact Gary D. Yacura (Reg. 35,416) at the telephone number of the undersigned below.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 02-2448 for any additional fees required under 37 C.F.R. § 1.16 or under 37 C.F.R. § 1.17; particularly, extension of time fees.

Respectfully submitted,

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630-1165P
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(Rev. 04/19/2000)

FILTERING CONTROL METHOD FOR IMPROVING IMAGE QUALITY OF BI-LINEAR INTERPOLATED IMAGE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an interpolation method adapted to enlargement of a low resolution image when the image digitized through a CCD (Charged-Coupled Device) has the low resolution, in particular to a filtering control method for improving the image quality of a bi-linear interpolated image which is capable of restoring a requested interpolated high resolution image from a low resolution image by finding a coefficient of a two-dimensional filter on the basis of a regularization image restoration method.

2. Description of the Prior Art

In the conventional technology, a still picture or a moving picture has or transmits a low resolution image because it can not physically satisfy a sensor having the low resolution or a nyquist value.

In addition, a compressed moving picture has or transmits the low resolution image due to its bit value problem.

For example, when the compressed moving picture having the low bit value is transmitted to a receiver and the receiver enlarges the transmitted moving picture, the resolution of the transmitted moving picture lowers due to a degradation phenomenon ect..

Accordingly, a method for getting a high resolution image from a low

resolution image is required.

In the meantime, the method for getting the high resolution image from the low resolution image is largely divided into an image expansion type method and an image enhancement type method.

First, the image expansion type method converts the size of the low resolution image into a requested size. The bi-linear interpolation method, a zero order expansion method, and a cubic spline method are comprised in the image expansion type method.

However, as described above, the image expansion type method has an image visibility lowering problem because when the image is interpolation-restored by the above-mentioned method such as the bi-linear interpolation method, zero order hold expansion method, cubic spline method, the outlines of the image is over-blurred.

Meanwhile, the image enhancement type method comprises many methods, but the image enhancement type method causes a computational complexity, accordingly the method is not suited to a real-time processing due to the its computational complexity.

In addition, when the image enhancement type method is used for getting the high resolution image from the low resolution image, setting of each parameter is not adaptable.

For example, there is a POCS (Projection Onto Convex Set) method for increasing the resolution of an image. In the POCS method, in use of time region information, it is assumed as correlation between the images is uniformly same, but actually the correlation between the images is not uniform.

In addition, there is a mapping method for mapping a non-uniform sample

of the low resolution image into a uniform sample of the high resolution image by using moving information and segmentation information of the image. However, the mapping method has the computational complexity problem, accordingly the mapping method is not suited to the real-time image data processing of the image processing system.

SUMMARY OF THE INVENTION

The object of the present invention is to provide a filtering control method for improving the image quality of a bi-linear interpolated image which is capable of improving the image quality of the interpolated image by using an interpolation method considering a real-time processing, a computational complexity and an efficiency when the digital video system seeks the interpolated image from the low resolution image.

The other object of the present invention is to provide the filtering control method for improving the image quality of the bi-linear interpolated image which is capable of finding a two-dimensional filter coefficient for getting the interpolated image from the low resolution image on the basis of a regularization image restoration method.

The other object of the present invention is to provide the filtering control method for improving the image quality of the bi-linear interpolated image which can approximate and find a PSF (Point Spread Function) for the bi-linear interpolated image from a modeling of the degraded image in the frequency region.

The other object of the present invention is to provide the filtering control method for improving the image quality of the bi-linear interpolated image which is

capable of performing a real-time adaptive processing by finding a filter coefficient from the bi-linear interpolated image and approximated PSF.

In the present invention, in order to find a filter coefficient for finding the interpolated image from the low resolution image on the basis of the regularization image restoration method, when H is the PSF (Point Spread Function), f is a requested high resolution image, Z is the low resolution image, g is the high resolution image gotten from the bi-linear interpolation method, an added function $M(f) = \| g-Hf \|^2 + \alpha \| Cf \|^2$ for finding the PSF(H) from an equation g=Bz=Hf+n (B, H are bi-linear interpolated filters, n is a noise component generated by the assumed H) is defined.

The filtering control method for improving the image quality of the bi-linear interpolated image can be implemented by finding the PSF(H) from the added function M(f) by using an equation $H(k,l) = \frac{G(k,l)}{F(k,l)}$.

The filtering control method for improving the image quality of the bi-linear interpolated image can be implemented by finding a PSF(P) of a f=Pg function by using an equation $P(k,l) = \frac{H^*(k,l)}{H^*(k,l)H(k,l) + C^*(k,l)C(k,l)}$ after finding the PSF(H).

The filtering control method for improving the image quality of the bi-linear interpolated image can restore the requested high resolution image(f) by finding an added filter coefficient Q of the PSF(P) and interpolation filter B from the equation f=Pg=PBz=Qz.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG.1 illustrates an image sample for getting a twice enlarged high resolution image according to the embodiment of the present invention.

FIG.2 illustrates an interpolation filter coefficient for getting the twice enlarged image according to the embodiment of the present invention.

FIG.3 illustrates an image sample for getting a three times enlarged high resolution image according to the other embodiment of the present invention.

FIG.4 illustrates the interpolation filter coefficient for getting the three times enlarged image according to the other embodiment of the present invention.

FIG.5 illustrates an image sample for getting a six times enlarged high resolution image according to the another embodiment of the present invention.

FIG.6 illustrates the interpolation filter coefficient for getting the six times enlarged image according to the another embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG.1 illustrates an image sample for getting a twice enlarged high resolution image according to the embodiment of the present invention.

As depicted in FIG.1, a ~ i illustrate low resolution pixels, A~D illustrate high resolution pixels. In addition, pixels depicted as 'x' illustrate pixels interpolated as twice by a twice interpolation filter coefficient.

FIG.2 illustrates the interpolation filter coefficient for getting a twice enlarged image according to the embodiment of the present invention. In other words, the interpolation filter coefficient for interpolating the twice enlarged image of FIG.1 is depicted in FIG.2.

As depicted in FIG.2, the high resolution image is gotten from the low resolution pixels a~i (3×3 pixels) inside of a circle of FIG.1 by using the interpolation filter coefficient.

FIG.3 illustrates an image sample for getting a three times enlarged high resolution image according to the other embodiment of the present invention.

As depicted in FIG.3, a~p illustrate the low resolution pixels, A~I illustrate the high resolution pixels using the filter according to the present invention.

FIG.4 illustrates the interpolation filter coefficient for getting the three times enlarged image according to the other embodiment of the present invention.

As depicted in FIG.4, three times enlarged pixels which are newly generated illustrated as triangles in FIG.3 are gotten from the low resolution pixels a~p (4×4 pixels) by using the interpolation filter coefficient of FIG.4.

FIG.5 illustrates the image sample for getting a six times enlarged high resolution image according to the another embodiment of the present invention. In other words, it illustrates the image sample for getting the six times enlarged high resolution image from the twice and three times interpolation filter coefficients by using the bi-linear interpolation method.

As depicted in FIG.5, pixels illustrated as a 'X' can be gotten by using the twice interpolation filter of FIG.2, and pixels illustrated as a triangle can be gotten by using the three times interpolation filter coefficient of FIG.4.

In addition, pixels illustrated as a quadrilateral can be gotten from the pixels generated by the twice and three times interpolation filter coefficients by using the bi-linear interpolation method.

FIG.6 illustrates the interpolation filter coefficient for getting the six times enlarged image according to the another embodiment of the present invention. In

other words, the interpolation filter coefficient for getting the six times enlarged image of FIG.5 is depicted in FIG.6.

Meanwhile, as depicted in FIG.2, FIG.4 and FIG.6, the value found by using the interpolation filter coefficient of the present invention has an integer value.

In addition, a 9bit shift is performed to the value calculated by the interpolation filter coefficient, accordingly there is no need to perform a floating point operation processing.

The twice, three times, six times interpolated images are depicted in FIG.1 ~ FIG.6, however the present invention is not limited by that, it can be adapted freely to a certain interpolation value.

Hereinafter, the filtering control method for improving the image quality of the bi-linear interpolated image will be described in more detail.

First, a spatially invariant PSF (Point Spread Function) for finding the interpolation filter coefficient according to the each interpolation value can be easily analyzed and approximated in the frequency region, accordingly the spatially invariant PSF (Point Spread Function) is considered from the bi-linear interpolated image.

After that, when it is assumed as the low resolution image is z, high resolution image gotten by the bi-linear interpolation method is g, high resolution image to be restored is f, the relation between the each image can be described as below.

[Equation 1]

$$g=Bz=Hf+n$$

Herein, the B, H, n are the bi-linear interpolation filters, H is the spatially invariant PSF defining the relation between the original high resolution image and high resolution image gotten by the interpolation method, and the n is a noise component generated by the assumed H.

Herein, when the noise component is neglected and a direct inverse is used in order to find the PSF(H), the PSF(H) can be described as below equation 2 in the frequency region.

[Equation 2]

$$H(k,l)=\frac{G(k,l)}{F(k,l)}$$

Herein, the $H(k,l)$ is the component in the k,l frequency region of the PSF(H), the $G(k,l)$ is the component in the k,l frequency region of the bi-linear interpolated image. In addition, the $F(k,l)$ is the component in the k,l frequency region of the high resolution image.

Meanwhile, the high resolution image f to be restored is unknown, the PSF(H) can be gotten from the bi-linear interpolated high resolution image through a statistical processing after performing an under-sample processing of various images as various value.

Herein, the high resolution image is gotten by using the PSF(H) found from the direct inverse. In other words, there is a system stabilization problem because the high resolution image gotten from the PSF(H) by using the direct inverse is overshoot in the region where the k,l have '0' value (in general, high frequency

region) in the frequency region, accordingly the regularization image restoration for improving the system stabilization is used to solve the problem.

The regularization image restoration method is used for restoring the image or finding a certain PSF, an added function M(f) for finding the PSF(H) by using the regularization image restoration method can be described as below equation 3.

[Equation 3]

$$M(f) = \| g-Hf \|^2 + \alpha \| Cf \|^2$$

Herein, the first term of the right side of Equation 3 illustrates the credibility of the bi-linear interpolated image, the second term of the right side illustrates increase of the stability of the system by providing the mitigation to the restored image.

In addition, the $\| . \|$ means a norm, the α is a regularization parameter for determining the credibility and mitigation of the original image. In addition, the C is the two-dimensional high frequency filter for determining the mitigation of the original image, in the present invention a two-dimensional Gaussian filter is used as the C.

When a gradient operator is adapted to Equation 3 in order to get the high resolution image, it can be described as below equation 4.

[Equation 4]

$$\square_f M(f) = -2H^T (g-Hf) + 2\alpha C^T Cf = 0$$

Herein, the T means a transpose of a matrix.

Meanwhile, conventionally a repetition method is used in order to get the high resolution image and regularization parameter, but it is not suited to the moving picture processing because the method causes lots of computational complexity.

Accordingly, in the present invention, the regularization parameter α is fixed as '1', and the high resolution image f can be found as below equation 5.

[Equation 5]

$$f=\frac{H^T g}{(H^T H + C^T C)}=Pg$$

When the PSF(P) is found by Equation 5, $PSF(P)=H/(H^TH+C^TC)$ requires the lots of computational complexity for calculating an inverse matrix, however the PSF(P) in Equation 5 is a block-circulant matrix, accordingly it can be easily calculated in the frequency region.

Accordingly, the PSF(P) can be found finally as below Equation 6.

[Equation 6]

$$P(k,l)=\frac{H^*(k,l)}{H^*(k,l)H(k,l)+C^*(k,l)C(k,l)}$$

Herein, the '*' means a complex-conjugate.

The PSF(P) can be found by using an IFT (Inverse Fourier Transform) from Equation 6.

The requested high resolution image f can be found as below Equation 7 by using the found PSF(P) and Equation 1.

[Equation 7]

$$f=Pg=PBz=Qz$$

The PSF(P) is the spatially invariant function, the bi-linear interpolation filter B can be easily found by the conventional technology, accordingly the added filter coefficient Q of the PSF(P) and bi-linear interpolation filter B can be found.

Herein, in order to reduce the computational complexity, the number of a kernel of the PSF(P) is set in accordance with the up-sampling value.

When the up-sampling value is 2 in the present invention, the number of the kernel is limited as 3, when the up-sampling value is 3, the number of the kernel is limited as 4.

When the up-sampling value is 2, it can be used in an application segment for enlarging the size of the image as twice at a post processor of the compressed digital image and in finding of a sub-pixel moving vector in a H.263 moving picture compressed method.

In addition, when the up-sampling value is 3, it can be used in using of a 1/3 unit moving vector in a H.26L moving picture compressed method.

Herein, the H.263 and H.26L are moving picture compressed standards presented in the ITU-T (International Telecommunications Union-Telecommunication).

As described above, the present invention can be used for improving the image quality at the post processor of the compressed digital image by using the

interpolation method for getting the interpolated high resolution image from the low resolution image when the resolution of the digital image lowers due to the low resolution image sensor.

In addition, the interpolation method of the present invention can improve the image quality by finding the moving vector of the moving picture compressed type.

What is claimed is :

1 A filtering control method for improving the image quality of a bi-linear interpolated image in methods for getting a high resolution image from a low resolution image, comprising :

restoring a requested high resolution image f by finding an added filter coefficient Q of a PSF(P) and a bi-linear interpolation filter B from an equation f=Pg=PBz=Qz, herein the f is the high resolution image as requested, P is the PSF (Point Spread Function), g is the high resolution image found by the bi-linear interpolation method, and z is the low resolution image.

2. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 1, wherein the high resolution image f can be restored by performing an added function M(f) definition process for finding the PSF(H) from an equation g = Bz = Hf+n, herein the B, H are bi-linear interpolation filters, and the n is a noise component generated by the assumed H.

3. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 1, wherein the high resolution image f is restored by finding a PSF(P) of a f=Pg function after finding the PSF(H) from the added function M(f).

4. The filtering control method for improving the image quality of the

bi-linear interpolated image according to claim 2, wherein the added function M(f) is defined as M(f)= $\| g-Hf \|^2+\alpha \| Cf \|^2$, herein the α is a regularization parameter, C is a two-dimensional high frequency filter for finding mitigation of the original image.

5. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 3, wherein the PSF(H) is found by using an equation $H(k,l)=\frac{G(k,l)}{F(k,l)}$, herein the $G(k,l)$ is the component in the k,l frequency region of the bi-linear interpolated image, and the $F(k,l)$ is the component in the k,l frequency region of the high resolution image.

6. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 1, wherein the PSF(P) can be found by getting an IFT (Inverse Fourier Transform) by an equation

$$P(k,l)=\frac{H^*(k,l)}{H^*(k,l)H(k,l)+C^*(k,l)C(k,l)}$$

7. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 4, wherein the regularization parameter α is fixed as '1' in order to reduce a computational complexity.

8. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 1 or 6, the number of a kernel of the PSF(P) is set in accordance with an up-sampling value of the image.

9. The filtering control method for improving image quality of the bi-linear interpolated image according to claim 4, wherein a two-dimensional gaussian filter is used as the two-dimensional high frequency filter C in order to determine the mitigation of the original image.

10. A filtering control method for improving image quality of a bi-linear interpolated image in methods for getting a high resolution image from a low resolution image, comprising :

defining an added function M(f) for finding a PSF(H) from an equation g=Bz=Hf+n (B, H are bi-linear filters, N is a noise component generated by an assumed H when the H is a PSF (Point Spread Function), F is a requested high resolution image, z is a low resolution image, and g is a high resolution image gotten by the bi-linear interpolation method ;

finding a PSF(P) of a f=Pg function after finding the PSF(H) from the defined added function M(f) ; and

restoring the requested high resolution image f by finding an added filter coefficient Q of the PSF(P) and interpolation filter B from the equation f=Pg=PBz=Qz.

11. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 10, wherein the added function M(f) is defined as $M(f)= \| g-Hf \|^2+\alpha \| Cf \|^2$, herein the α is a regularization parameter, and C is a two-dimensional high frequency filter for finding the mitigation of the original image.

12. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 10, the PSF(H) is found by an equation $H(k,l)=\frac{G(k,l)}{F(k,l)}$, herein the $G(k,l)$ is the component in the k,l frequency region of the bi-linear interpolated image, and the $F(k,l)$ is the component in the k,l frequency region of the high resolution image.

13. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 10, wherein the PSF(P) is found by using an IFT (Inverse Fourier Transform) from an equation

$$P(k,l)=\frac{H^*(k,l)}{H^*(k,l)H(k,l)+C^*(k,l)C(k,l)}$$

14. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 11, wherein the regularization parameter α is fixed as '1' in order to reduce a computational complexity.

15. The filtering control method for improving the image quality of the bi-linear interpolated image according to claim 10 or claim 13, the number of a kernel of the PSF(P) is differently set in accordance with an up-sampling value of the image.

16. The filtering control method for improving image quality of the bi-linear interpolated image according to claim 11, wherein a two-dimensional

gaussian filter is used as the two-dimensional high frequency filter C in order to determine the mitigation of the original image.

ABSTRACT OF THE DISCLOSURE

The present invention relates to an interpolation method for enlarging a digital image or predicting a moving vector of a compressed image system as a sub-pixel unit when the image digitized through a CCD (Charge Coupled Device) camera ect. has a low resolution in a video phone or video conference or general digital video system, particularly the present invention can be adapted to a post processor of a compressed digital image in order to improve the image quality, and can be used for finding a moving vector of a moving picture compressed type, accordingly the present invention is capable of improving the image quality.

FIG. 1

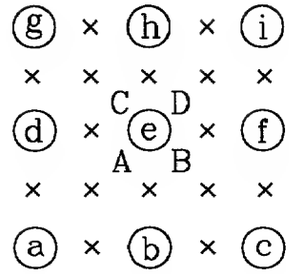

FIG. 2

$$\begin{bmatrix} A \\ B \\ C \\ D \end{bmatrix} = 1/512 \begin{bmatrix} 1 & 94 & -15 & 94 & 391 & -15 & -15 & -15 & -8 \\ -15 & 86 & -9 & -13 & 370 & 113 & -6 & -14 & -18 \\ -15 & -13 & -6 & 86 & 370 & -14 & 9 & 113 & -18 \\ 6 & -14 & -14 & -14 & 349 & 107 & -14 & 107 & 11 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \\ d \\ e \\ f \\ g \\ h \\ i \end{bmatrix}$$

FIG. 3

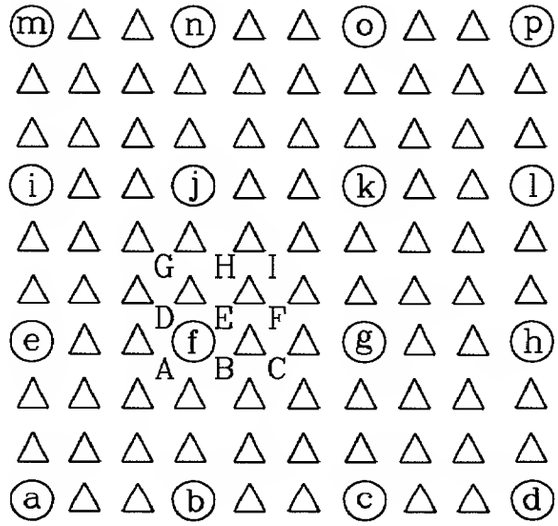

FIG. 4

$$\begin{bmatrix} A \\ B \\ C \\ D \\ E \\ F \\ G \\ H \\ I \end{bmatrix} = 1/512 \begin{bmatrix} -4 & 60 & -22 & 0 & 104 & 387 & -3 & 0 & -4 & 7 & -13 & 0 & 0 & 0 & 0 & 0 \\ -15 & 71 & -22 & 0 & 11 & 422 & 63 & 0 & -11 & 12 & -19 & 0 & 0 & 0 & 0 & 0 \\ -12 & 44 & 9 & -8 & -17 & 307 & 215 & -8 & -6 & 4 & -11 & -5 & 0 & 0 & 0 & 0 \\ -16 & -8 & -16 & 0 & 103 & 372 & -3 & 0 & 9 & 91 & -20 & 0 & 0 & 0 & 0 & 0 \\ -12 & -4 & -25 & 0 & 9 & 403 & 61 & 0 & -12 & 107 & -15 & 0 & 0 & 0 & 0 & 0 \\ -8 & -9 & -23 & -5 & -19 & 284 & 229 & -10 & -13 & 69 & 29 & -12 & 0 & 0 & 0 & 0 \\ -8 & -10 & -6 & 0 & 44 & 212 & -16 & 0 & 71 & 269 & -11 & 0 & -11 & -16 & -16 & 0 \\ -4 & -9 & -10 & 0 & -6 & 226 & 52 & 0 & 2 & 272 & 22 & 0 & -6 & -15 & -12 & 0 \\ -2 & -8 & -12 & -2 & -16 & 160 & 100 & -9 & -15 & 213 & 143 & -2 & -9 & -12 & -15 & -2 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \\ d \\ e \\ f \\ g \\ h \\ i \\ j \\ k \\ l \\ m \\ n \\ o \\ p \end{bmatrix}$$

FIG. 5

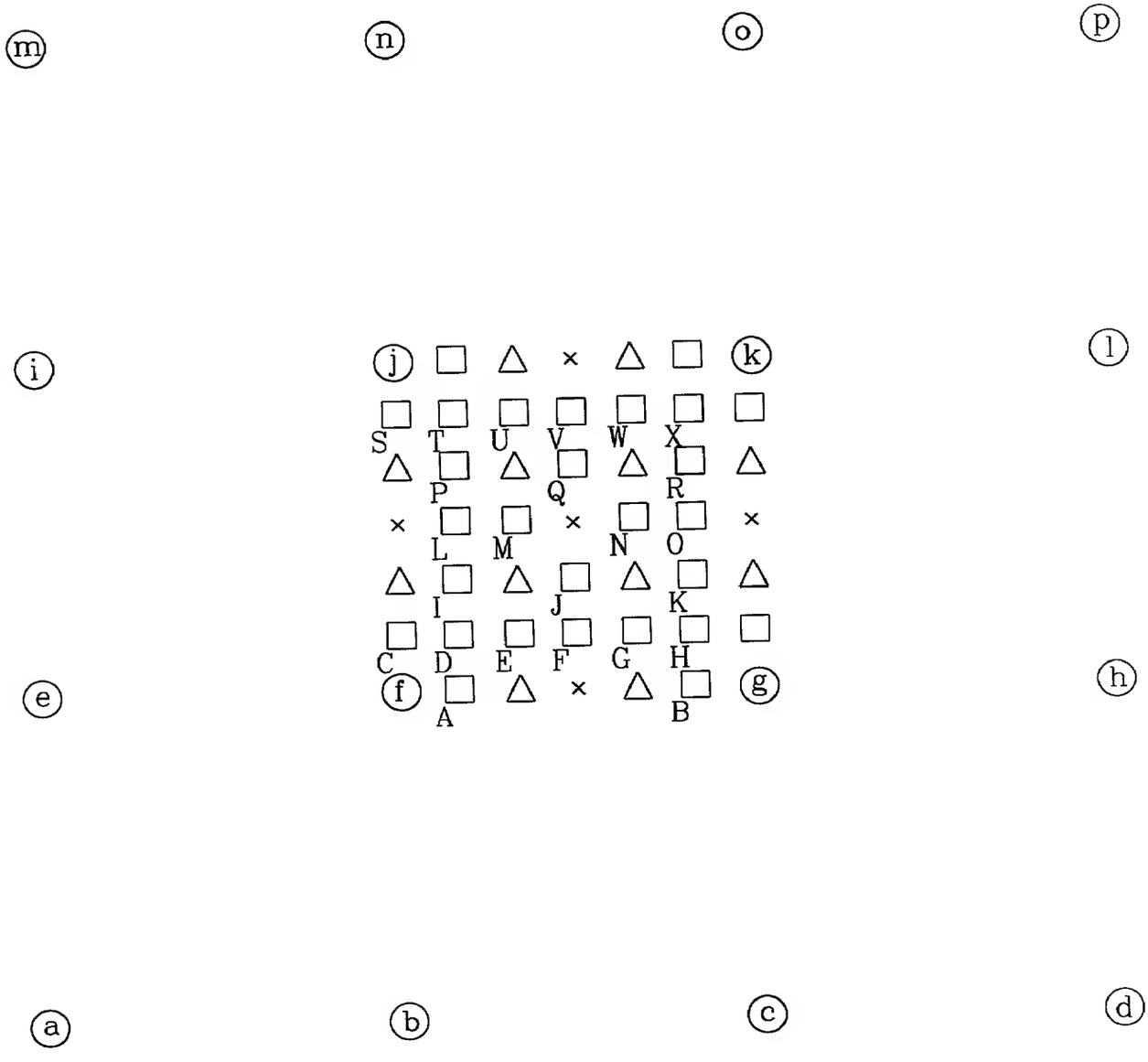

FIG. 6

$$\begin{bmatrix} A \\ B \\ C \\ D \\ E \\ F \\ G \\ H \\ I \\ J \\ K \\ L \\ M \\ N \\ O \\ P \\ Q \\ R \\ S \\ T \\ U \\ V \\ W \\ X \end{bmatrix} = 1/512 \begin{bmatrix} -7 & 81 & -14 & 0 & 52 & 405 & 24 & 0 & -13 & -2 & -14 & 0 & 0 & 0 & 0 & 0 \\ -6 & 23 & 52 & -12 & -9 & 201 & 302 & -12 & -3 & -5 & -13 & -6 & 0 & 0 & 0 & 0 \\ -8 & 43 & -16 & 0 & 99 & 382 & -9 & 0 & -3 & 38 & -14 & 0 & 0 & 0 & 0 & 0 \\ -10 & 38 & -20 & 0 & 54 & 397 & 27 & 0 & -7 & 49 & -16 & 0 & 0 & 0 & 0 & 0 \\ -13 & 33 & -23 & 0 & 10 & 413 & 62 & 0 & -12 & 59 & -17 & 0 & 0 & 0 & 0 & 0 \\ -12 & 26 & -15 & -3 & -4 & 354 & 142 & -5 & -11 & 48 & -4 & -4 & 0 & 0 & 0 & 0 \\ -10 & 17 & -8 & -7 & -13 & 295 & 221 & -9 & -10 & 36 & 9 & -9 & 0 & 0 & 0 & 0 \\ -5 & 4 & 18 & -11 & -9 & 197 & 302 & -9 & -5 & 17 & 24 & -11 & 0 & 0 & 0 & 0 \\ -14 & -6 & -21 & 0 & 56 & 338 & 29 & 0 & -2 & 99 & -17 & 0 & 0 & 0 & 0 & 0 \\ -10 & -7 & -24 & -3 & -5 & 344 & 145 & -5 & -12 & 88 & 7 & -6 & 0 & 0 & 0 & 0 \\ -4 & -13 & -16 & -11 & -10 & 194 & 301 & -6 & -6 & 39 & 60 & -16 & 0 & 0 & 0 & 0 \\ -12 & -13 & -9 & 0 & 53 & 363 & 26 & 0 & 1 & 111 & -8 & 0 & 0 & 0 & 0 & 0 \\ -9 & -14 & -11 & 0 & 19 & 356 & 67 & 0 & -6 & 109 & 1 & 0 & 0 & 0 & 0 & 0 \\ -9 & -9 & -14 & -2 & -9 & 261 & 195 & -5 & -9 & 74 & 45 & -6 & 0 & 0 & 0 & 0 \\ -12 & -5 & -13 & -4 & -5 & 174 & 282 & -9 & -5 & 42 & 79 & -12 & 0 & 0 & 0 & 0 \\ -6 & -10 & -8 & 0 & 19 & 219 & 18 & 0 & 37 & 271 & 6 & 0 & -9 & -16 & -9 & 0 \\ -8 & -9 & -6 & 1 & -11 & 193 & 76 & -4 & -7 & 243 & 83 & -4 & -4 & -14 & -14 & -1 \\ -1 & -8 & -11 & -4 & -8 & 102 & 156 & -13 & -8 & 142 & 206 & -10 & -1 & -11 & -15 & -4 \\ -4 & -5 & -3 & 0 & 23 & 153 & -16 & 0 & 83 & 330 & -13 & 0 & -13 & -16 & -7 & 0 \\ -3 & -5 & -4 & 0 & 6 & 151 & 0 & 0 & 45 & 338 & 15 & 0 & -11 & -9 & -11 & 0 \\ -2 & -5 & -5 & 0 & -10 & 149 & 15 & 0 & 7 & 347 & 43 & 0 & -9 & -2 & -16 & 0 \\ -2 & -4 & -6 & -1 & -12 & 125 & 35 & -4 & -5 & 304 & 111 & -4 & -6 & -3 & -14 & -2 \\ -1 & -4 & -6 & -1 & -14 & 102 & 55 & -8 & -16 & 260 & 179 & -9 & -4 & -4 & -13 & -4 \\ -1 & -4 & -6 & -2 & -7 & 62 & 104 & -12 & -8 & 172 & 255 & -11 & -2 & -9 & -14 & -5 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \\ d \\ e \\ f \\ g \\ h \\ i \\ j \\ k \\ l \\ m \\ n \\ o \\ p \end{bmatrix}$$

BIRCH, STEWART, KOLASCH & BIRCH, LLP

PLEASE NOTE: YOU MUST COMPLETE THE FOLLOWING:

COMBINED DECLARATION AND POWER OF ATTORNEY FOR PATENT AND DESIGN APPLICATIONS

ATTORNEY DOCKET NO

As a below named inventor, I hereby declare that: my residence, post office address and citizenship are as stated next to my name; that I verily believe that I am the original, first and sole inventor (if only one inventor is named below) or an original, first and joint inventor (if plural inventors are named below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

Insert Title: FILTERING CONTROL METHOD FOR IMPROVING IMAGE QUALITY OF BI-LINEAR INTERPOLATED IMAGE

Fill in Appropriate Information - For Use Without Specification Attached:

the specification of which is attached hereto. If not attached hereto,

the specification was filed on _____ as United States Application Number _____; and /or

the specification was filed on _____ as PCT International Application Number _____; and was amended under PCT Article 19 on _____ (if applicable)

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56.

I do not know and do not believe the same was ever known or used in the United States of America before my or our invention thereof, or patented or described in any printed publication in any country before my or our invention thereof or more than one year prior to this application, that the same was not in public use or on sale in the United States of America more than one year prior to this application, that the invention has not been patented or made the subject of an inventor's certificate issued before the date of this application in any country foreign to the United States of America on an application filed by me or my legal representatives or assigns more than twelve months (six months for designs) prior to this application, and that no application for patent or inventor's certificate on this invention has been filed in any country foreign to the United States of America prior to this application by me or my legal representatives or assigns, except as follows.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 (a)-(d) of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Insert Priority Information: (if appropriate)

Prior Foreign Application(s)

(Number)	(Country)	(Month/Day/Year Filed)	Priority Claimed
45805/1999	Korea	10/21/1999	☒ Yes ☐ No
			☐ Yes ☐ No
			☐ Yes ☐ No
			☐ Yes ☐ No
			☐ Yes ☐ No

I hereby claim the benefit under Title 35, United States Code, §119(e) of any United States provisional application(s) listed below.

Insert Provisional Application(s): (if any)

(Application Number)	(Filing Date)

All Foreign Applications, if any, for any Patent or Inventor's Certificate Filed More Than 12 Months (6 Months for Designs) Prior To The Filing Date of This Application:

Insert Requested Information: (if appropriate)

Country	Application No.	Date of Filing (Month/Day/Year)

I hereby claim the benefit under Title 35, United States Code, §120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Insert Prior U.S. Application(s): (if any)

(Application Number)	(Filing Date)	(Status - patented, pending, abandoned)

I hereby appoint the following attorneys to prosecute this application and/or an international applicatio based on this application and to transact all business in the Patent and Trademark Office connected therewit and in connection with the resulting patent based on instructions received from the entity who first sent th application papers to the attorneys identified below, unless the inventor(s) or assignee provides said attorne with a written notice to the contrary:

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PLEASE NOTE: YOU MUST COMPLETE THE FOLLOWING:

I hereby declare that all statements made herein of my own knowledge are true and that all statement made on information and belief are believed to be true; and further that these statements were made with th knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardiz the validity of the application or any patent issued thereon.

Full Name of First or Sole Inventor
Insert Name of Inventor
Insert Date This Document is Signed
Insert Residence
Insert Citizenship
Insert Post Office Address

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Full Name of Fourth Inventor, if any: see above

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Residence (City, State & Country):

CITIZENSHIP:

POST OFFICE ADDRESS (Complete Street Address including City, State & Country):

Full Name of Fifth Inventor, if any: see above

GIVEN NAME	FAMILY NAME	INVENTOR'S SIGNATURE	DATE*

Residence (City, State & Country):

CITIZENSHIP:

POST OFFICE ADDRESS (Complete Street Address including City, State & Country):

* DATE OF SIGNATURE